

James B. Francis,
Engineer.

JAMES BICHENO FRANCIS.

By HIRAM F. MILLS.

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OUR friend, and the friend of this institution, whose name has for five years stood first in the list of members of this corporation, passed on to his new field of usefulness on the 18th of last September. From its organization for twenty-seven years Mr. James B. Francis has attended the meetings of this board, worked on its committees, advised and encouraged the Faculty of the Institute, and has been a personal and professional aid to many of its graduates.

Born at Southleigh, Oxfordshire, England, on May 18, 1815, Mr. Francis, like his loved friend, Mr. Hoadley—whose memory we all revere—began the work which led on to his profession at the early age of fourteen. Mr. Hoadley at that age began work in a machine shop, and Mr. Francis began assisting the engineer in constructing harbor works in Porth Cawl in South Wales, of which his father was superintendent. Two years later, in 1831, he was employed on the construction of the Grand Western Canal in Devonshire and Somersetshire. In the spring of 1833, before he was eighteen years old, he emigrated to this country, and soon found employment as an assistant engineer under William Gibbs McNeil and George W. Whistler, on the New York, Providence and Boston Railroad.

In 1834 Mr. Francis went with Major Whistler to Lowell, and began his work there by making working drawings of the details of one of the locomotives built by Stephenson for the Boston and Lowell Railroad, for reproduction in the machine shop of the Proprietors of Locks and Canals on Merrimack River. He remained as assistant engineer under Major Whistler until 1837, when the latter left Lowell and soon after went to Russia to introduce railway construction in that country, and Mr. Francis, at the age of twenty-two, was made chief engineer of the Proprietors of Locks and Canals on Merrimack River, which position he held for forty-eight years.

In 1845 he was invited by Mr. Storrow to assist him in developing the water power of the Merrimack River at what is now Lawrence,

but the Proprietors of Locks and Canals concluded that they needed him more at Lowell; they consequently increased his salary, and on September 27, 1845, appointed him their agent and engineer, and for the following forty years he had the management of the water power there, and the construction of the numerous improvements that have been made in the works connected with it. His duties also included the position, without name, of consulting engineer to the various manufacturing corporations at Lowell. Seeing that the performance of these duties in a manner satisfactory to him required greater preliminary training in mathematics and applied mechanics than his early education had afforded, he applied himself assiduously to the study of these subjects, taking by himself, in the leisure hours of a very busy life, an advanced course of study in these subjects, which put him abreast of the best educated engineers of his generation.

His habits of thought were methodical. He was often asked by the directors of his company, or by the agents of the manufacturing companies, in regard to questions concerning their peculiar departments of business, in such variety that no one not in the special business could be expected to give advice; but he, taking the question definitely in mind, went to his office and began a page of his calculation book with "Mr. — wants to know" so and so. He would then write out in full whatever of value he could find published upon that subject, together with his conclusions, and when he met his questioner again was ready to discuss the subject in all its bearings and give intelligent advice. From this habit of thoroughly investigating the subjects that came before him, and writing out his data and conclusions in form for convenient future reference, he came to be rightly acknowledged as an authority on a great variety of subjects.

The experiments of Eaton Hodgkinson on the best form for cast-iron beams had been published three years previously, but before using the results in an important position Mr. Francis preferred to try beams made of the full size required, and of iron commonly used for such purposes in Lowell. He accordingly had a beam constructed having a span of nineteen feet and a depth of fifteen and one eighth inches, and on January 7, 1845, broke it with 69,821 pounds applied at the center. He then altered the pattern and broke another beam with a load of 114,000 pounds. These are the earliest experiments I have found upon large beams of American iron.

In 1846 Mr. Francis made designs for the enlargement of the water power at Lowell, and constructed the grand canal with its river

wall thirty-six feet in height, the body of which is a dry stone wall with joints perpendicular to the battering face, and having a water tight lining of small stones in cement on the canal side. He here introduced vertical screws for hoisting the head gates with nuts driven by a turbine. The entire cost of these improvements, amounting to \$530,000, very slightly exceeded his estimates. In constructing the guard dam at the head gates of this canal, in 1847, he determined the proper height by investigating the past great freshets that had occurred on the river, and concluded that the guard dam and lock at the old canal required to be raised. They were built to the height of the new guard dam in 1848. Then Mr. Francis concluded that the lock gates were insufficient to withstand such a freshet as occurred in 1785, and recommended the construction of a great gate twenty-seven feet wide and twenty-five feet high. This was accordingly built in 1850, and hung high in the air over the lock. The need of this gate was beyond the comprehension of most of the people, and it was not uncommonly spoken of as Francis' folly. Only two years later, in April, 1852, a freshet arose higher than ever before above the dam until there was imminent danger of destroying an immense amount of property.

Mr. Francis, in writing of the great freshets in the Merrimack River, modestly says: "The great gate in the guard lock was hung in 1850, two years only before the freshet of 1852, when it was dropped. This is the only occasion when it has been of service, but it is kept in readiness for use at any time. The new gate was placed across the lock about forty-six feet below the old gates, which were not changed, but were supposed to be sufficient to hold until the water attained the height it was in 1785, or to about thirteen and a half feet above the top of the dam; but it proved to be otherwise. At three o'clock in the morning of April 22, 1852, the water found its way round the heel post of the westerly gate, the height of water at the time being eleven feet ten and a quarter inches above the top of the dam. Preparations were immediately made to drop the new gate, which was done half an hour afterwards. The water continued to rise until one o'clock the next morning, rising in the interval two feet two and three quarters inches, or to the height of fourteen feet one inch above the top of the dam, which was the maximum height attained in this freshet, or indeed of any other of which we have any record or tradition."

The day after the gate was dropped, but before the water began to recede, the *Lowell Journal* said: "Lowell has probably escaped a great calamity by the wise foresight and timely precaution of one eminently practical man—James B. Francis, Esq., Agent of the Proprietors of Locks and Canals on Merrimack River. Mr. Francis, a few years since, anticipating the possibility of an event such as we have just realized, and foreseeing that the strong works at the 'Guard Locks' might fail in such an emergency, caused to be constructed a massive, higher and stronger gate, which has ever since been kept in a position to be lowered to its place at a moment's notice. Early yesterday morning it was clearly evident that the safety of the Company's works, and consequently of a goodly portion of the city, required the lowering of the huge gate to its post of duty. It was promptly done, and danger from that source was no longer within the range of possibilities."

The *Boston Daily Advertiser* a few days later said: "It is certainly somewhat remarkable that a freshet occurring only once in a century should happen only two years after special preparation had been made for it, and the inhabitants of Lowell, as well as the proprietors of the mills, have great cause to thank the gentlemen who so promptly decided to take measures to guard against what every one considered a very remote contingency, and what many considered a useless expenditure of money.

"It is awful to think of what would have been the inevitable result if the new works had not been constructed. Every vestige of the old guard gates would have been carried away, and a mighty and uncontrollable river would have swept through the heart of Lowell, destroying everything in its course."

A few years later citizens of Lowell presented to Mr. Francis a service of silver "in token of their admiration of his foresight and sagacity in constructing a gate at the Guard Locks, thereby effectually protecting the city of Lowell against those casualties to which, as the freshet of 1852 fully demonstrated, it must be exposed."

In 1849 Mr. Francis was sent to England by the manufacturing companies of Lowell to observe the methods in use there for preserving timber from decay, which resulted in the construction of works at Lowell for kyanizing and for burnettizing timber with experiments upon wood so treated, some of the results of which are published in the transactions of the American Society of Civil Engineers.

Among other notable engineering works at Lowell are his ingenious and skillful application of hydraulic lifts to the guard gates of the Pawtucket Canal, designed in 1870, and the reconstruction of the Pawtucket Dam across the Merrimack River in 1875-76.

A prominent part of Mr. Francis' duty at Lowell was to distribute the water power among the several corporations in accordance with their respective rights; this has called for the execution of many original hydraulic experiments on a large scale. Selections from those made from 1847 to 1852 on hydraulic motors and on the flow of water over weirs and in short canals of uniform rectangular section were published in 1855, in the work entitled *Lowell Hydraulic Experiments*. In the second edition, published in 1868, were extensive additions upon the subject of the flow of water in open canals from experiments made from 1856 to 1860, and very interesting results of experiments made in 1854 upon the flow of water through submerged orifices and diverging tubes. The third and fourth editions were issued in 1871 and 1883.

This work forms an era in the engineering literature of America as well as in the growth of the profession. The extreme accuracy of the work and the care with which all interfering circumstances were avoided and the clearness and fullness with which all of the actual conditions are presented give it a character which younger engineers have been proud to emulate, and it has had a remarkably great influence in the growth of the engineering profession in America.

Mr. Francis was elected Fellow of the American Academy of Arts and Sciences, November 13, 1844. On February 14, 1865, his memoir, *On the Strength of Cast-Iron Pillars with tables for the use of Engineers, Architects and Builders*, was presented to the academy. Prof. Daniel Treadwell, addressing the academy, said: "Mr. Francis has made a most thorough examination of all the experiments that have been published, or that came within his reach, with the conclusions which have been drawn from them, together with the formulas and rules that have been proposed for practical constructions. Proceeding thus he has, after a careful and patient examination of the experiments and the reasoning of the several investigations, selected such of the conclusions and formulas as have appeared to him quite trustworthy, and from combining and in some cases modifying these he has calculated a most elaborate set of tables, by which the architect or practical workman can find a column suited to any structure, and

which may be relied upon as safe for all purposes, ordinary, or even extraordinary. I consider the paper thus produced by Mr. Francis as of great value, and believe that it will become a work of the first authority and of constant reference for the builder."

This paper was worked out to supply a need in the profession shown by the fall of the Pemberton Mill in Lawrence, January 10, 1860, an account of which was published by Mr. Francis in the *Journal of the Franklin Institute* immediately after.

In the same journal may be found important papers by Mr. Francis : in 1867 on experiments on the evaporation of steam boilers used for heating purposes, a description of cofferdam at Turner's Falls and formulas and tables for the shafting of mills and factories ; in 1870, experiments on the evaporation of a Corliss boiler ; and in 1875, report on a test trial of a Swain turbine water wheel.

Mr. Francis was elected a member of the American Society of Civil Engineers at its first meeting, November 5, 1852, and was president of the society from November 3, 1880, to January 18, 1882, and on the 5th of April, 1892, was elected an honorary member. To this society he contributed many valuable papers, and joined in many of the discussions. Among the papers containing additions to the knowledge of the profession are his "Experiments on the Deflection of Continuous Beams," "Experiments on the Flow of Water over Submerged Weirs," "Experiments on the Preservation of Timber," and "Experiments on the Percolation of Water through Portland Cement Mortar," contained in his paper on "High Walls or Dams to Resist the Pressure of Water." He also contributed reports on the failure of the dam on Mill River, and on the cause of the failure of the South Fork Dam ; also papers on durability of cast-iron water mains, the Provincetown dike, translation of Darcy's results on flow of water through cast-iron pipes ; on the cause of the maximum velocity of water flowing in open channels being below the surface ; distribution of rainfall over New England during the great storm of October 3 and 4, 1869 ; experiments on the Humphrey turbine water wheel ; stoppage of flow in a water main by anchor ice ; and on the effect of a rapidly increasing supply of water to a stream on the flow below the point of supply. And in his address as president of the society, delivered at Montreal in 1881, he gave the result of his observations on the formation of anchor ice.

Mr. Francis became a member of the Boston Society of Civil Engineers July 3, 1848, and was its president in 1874. To the meet-

ings of these societies of engineers he was always heartily welcomed, and was listened to with profound respect. His character as an investigator seeking only the truth, as a skillful engineer adopting the best means to accomplish the end desired, and as a pure-minded, honorable man, impressed his associates; and with the greatest confidence in his integrity there was added the enjoyment of his geniality and helpful kindness.

He received from Dartmouth College, in 1851, the honorary degree of Master of Arts, and in 1858 the same degree was conferred by Harvard College. He was a member of the American Philosophical Society of Philadelphia, and from 1864 to 1868 a member of the Boston Society of Natural History. He was also honorary member of Winchester Historical and Genealogical Society, of the Arkwright Club, of the Trinity Historical Society of Dallas, Texas, and of the American Society of Irrigation Engineers of Salt Lake City, Utah.

Mr. Francis has had a wide practice throughout the country as consulting engineer in hydraulic work, in which department he has been regarded as the head of his profession in this country. Among the more important subjects on which he has given advice are fifty water powers in nine States and two provinces, including a plan for preventing the recession of St. Anthony's Falls on the Mississippi River, and designs for reconstruction of the Holyoke Dam; also water works in eighteen cities of five States and one province, including a report on the design for the Quaker Bridge Dam on Croton River; also many foundations of important structures, including that of Trinity Church tower in Boston; also upon irrigation in California. He has been employed as an expert in a great number of cases at law.

Mr. Francis resigned the office of agent and engineer of the Proprietors of Locks and Canals on Merrimack River, January 1, 1885, which he had held from September 27, 1845. This was fifty years after he entered the service of the company, and his friends—the second generation of directors during his service—then presented to him a beautiful service of silver, and to their expressions of trust and friendship added the declaration, “To the eminent ability and wisdom which have distinguished your administration, the marked success of the Lowell manufacturers has been largely due.” He was then appointed consulting engineer of the company, which position he held at the time of his death, September 18, 1892.

Outside of his profession he was held in the highest esteem by the community for his sterling integrity and kindliness. Everybody had

the utmost confidence in his judgment, in his fairness, in his unselfishness and in his great executive ability. He served one year in the State Legislature, five years in the city government, four years on the school committee, two years as director of the city library, one year as president of Middlesex Mechanics Association, twenty years as president of Stony Brook Railroad, thirty-two years as director of the Railroad National Bank, and forty-three years as director of the Lowell Gas Light Company.

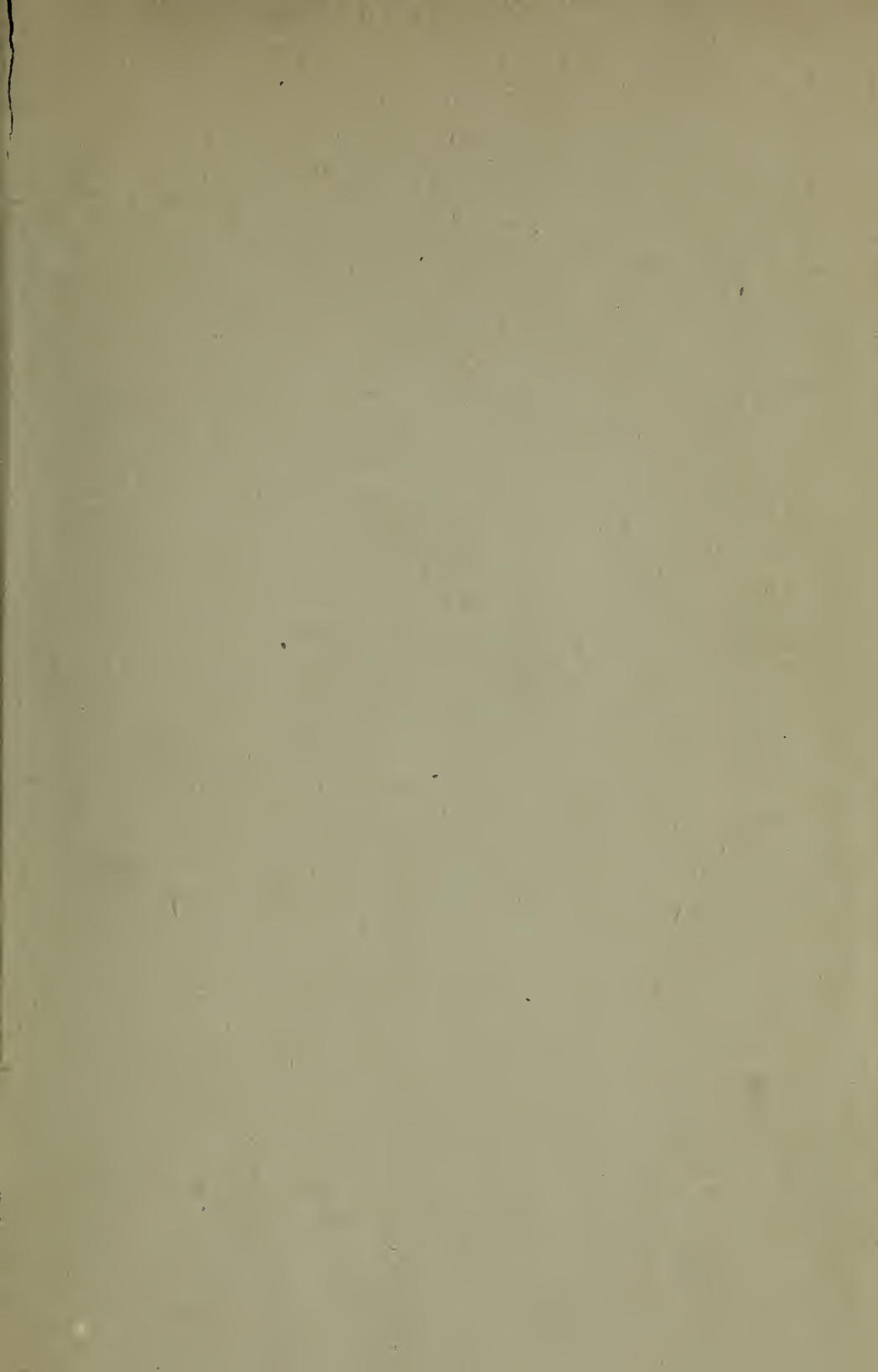
He was frequently appointed a commissioner to decide important cases, in which his professional knowledge and his judicial mind would give advantages over others. Among the more important of these commissions were those to assess damages for the diversion of Sudbury River by the city of Boston, in 1876, and to report on method of preventing floods in the valley of Stony Brook, in 1886; also to design and construct for the State of Massachusetts the Provincetown Dike, in 1867-69.

By the will of his friend, the eminent engineer Uriah A. Boyden, Mr. Francis was made one of the trustees of a fund, amounting to two hundred and thirty thousand dollars, to establish an observatory, or to help others to maintain an observatory for astronomical research "at such an elevation as to be free, so far as practicable, from the impediments to accurate observations which occur in the observatories now existing, owing to atmospheric influences." To determine where best to expend this money Mr. Francis visited, principally at his own expense, nearly if not quite all of the observatories of this country. The trustees finally transferred the property to the president and fellows of Harvard College, to be used for the purpose intended with other funds of the observatory, resulting in the establishment of an observatory near Arequipa in Peru, at an altitude of more than eight thousand feet above the sea.

With the unsurpassed activities of his wonderfully useful life, in which he illustrated the noble Christian virtues, he yet had time and thought and activity to devote to the interests of St. Anne's Church, of which he was member, warden and vestryman, and an interested director of their orphanage.

In all the relations of life he was the faithful, single-minded, courageous, reliable, earnest, far-sighted, honorable man. His memory is a blessing to his country.

Lawrence, December 11, 1892.



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